Mechanical Structure for FST

28 February 2019 @ F2F meeting

Han-Sheng Li, Yi Yang — Department of Physics, NCKU

Chung-De Chen, Pei-Chia Chung, Bing-Teng Hong, Jian-Yu Wang, Tian-Shiang Yang — Department of Mechanical Engineering, NCKU

Tang-Shiang Chang, Yuan-Ruey Chuang, Yean Ho Liao — Aerospace Industrial Development Corporation

The Forward Silicon Tracker

Flexible hybrid PCB: **SDU/IU**

Inner Signal Cable: **BNL**

T-Board: **SDU/IU**

APV25 Chip: **UIC**

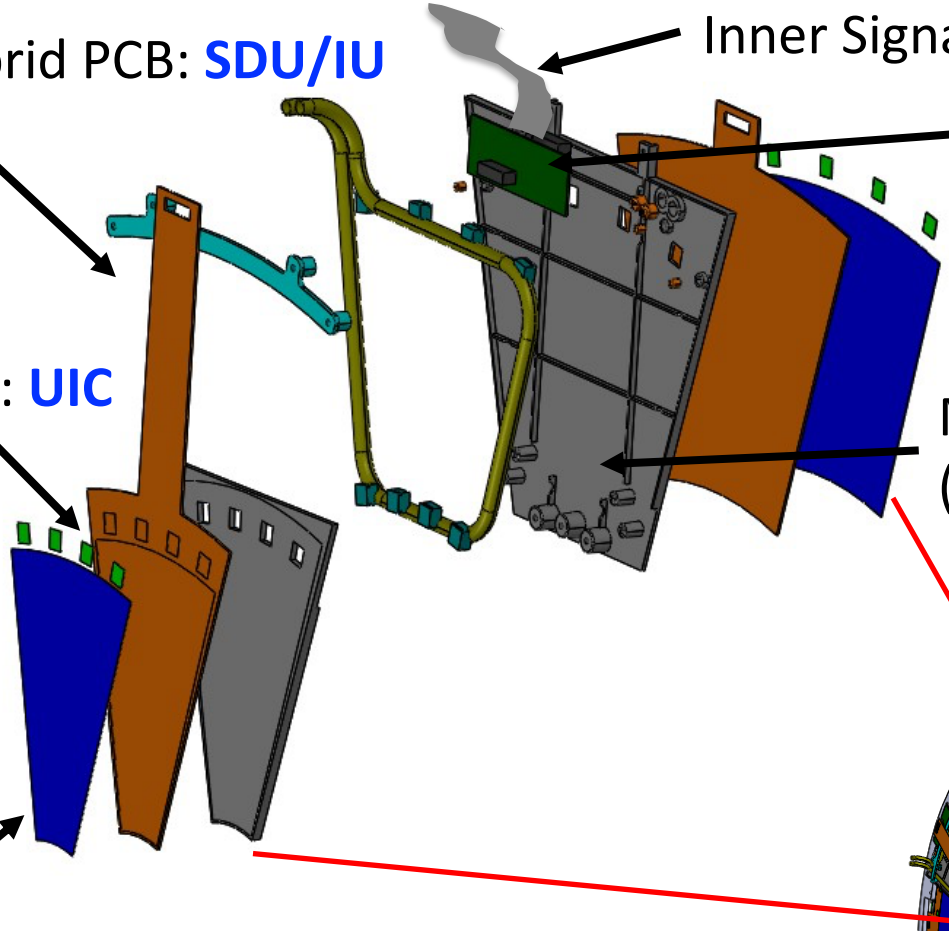
Mechanical Structure
(+ cooling pipe): **NCKU/AIDC**

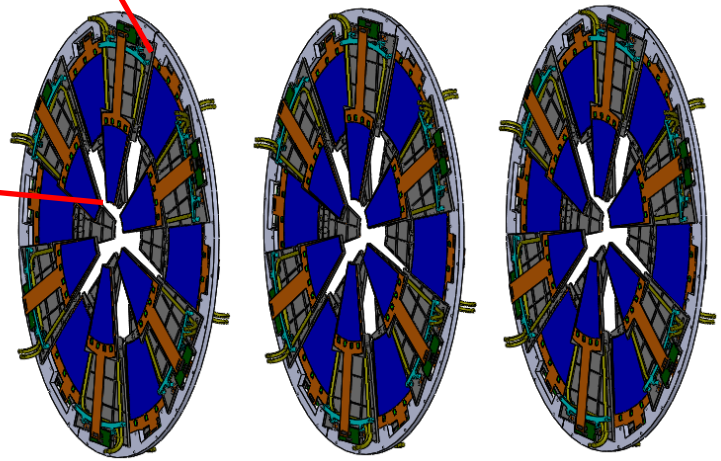
Supporting Structure &
Integration: **BNL**

Silicon sensor: **UIC/SDU/NCKU**

Cooling: **BNL/NCKU**

Simulation: **NCKU/IISER/BNL**

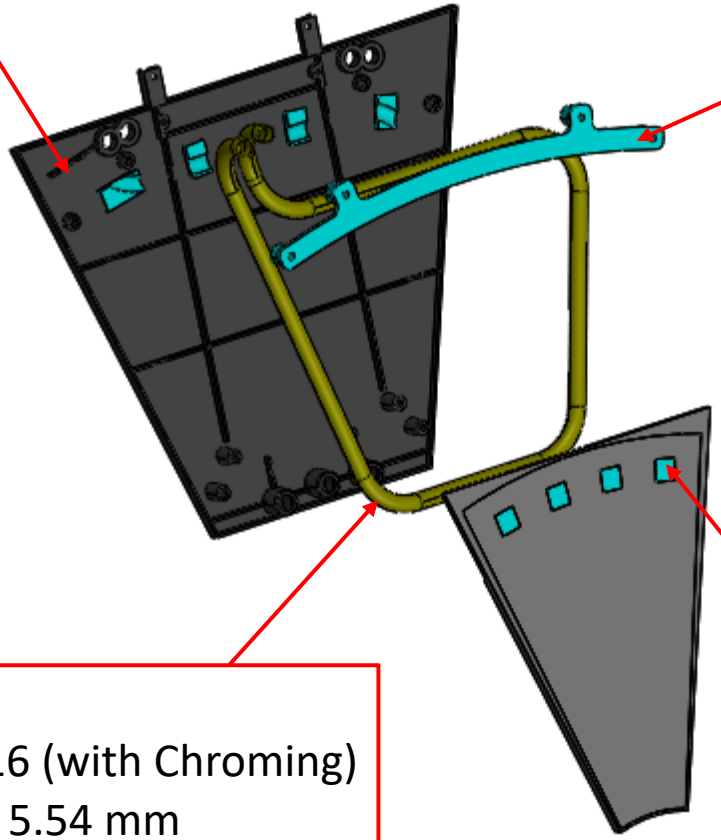




The Final Design

Main structure:
- ❑ Material: PEEK + 30% CF or PEEK (TBD)
- ❑ Thermal Conductivity: 0.37 or 0.24 W/m/K

Tube fixture:
- ❑ Material: ABS



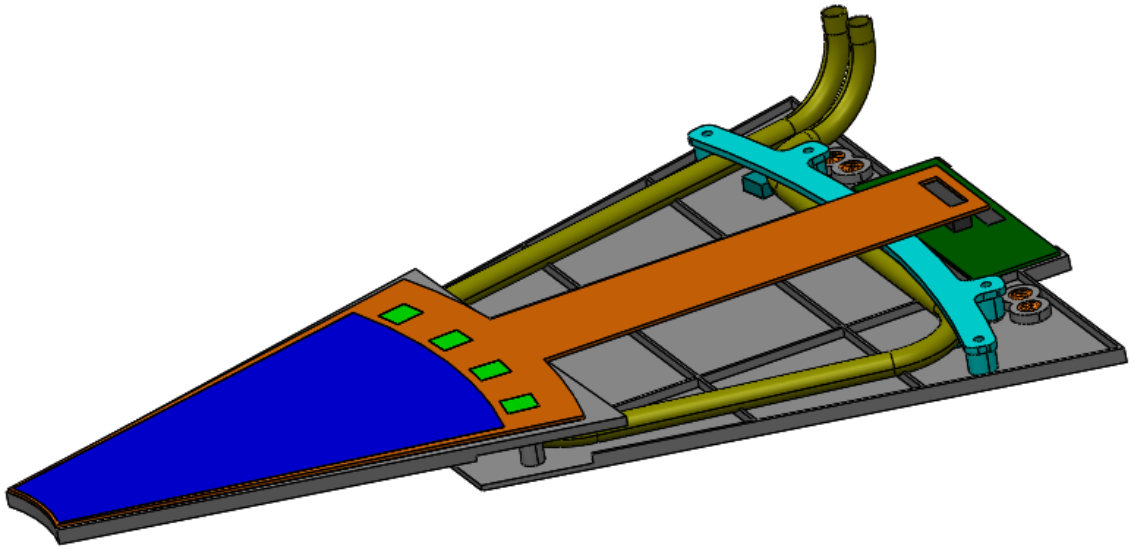
Tube:
- ❑ Material: Stainless 316 (with Chroming)
- ❑ Size: OD 6.35 mm, ID 5.54 mm
- ❑ Thermal Conductivity: 14 W/m/K

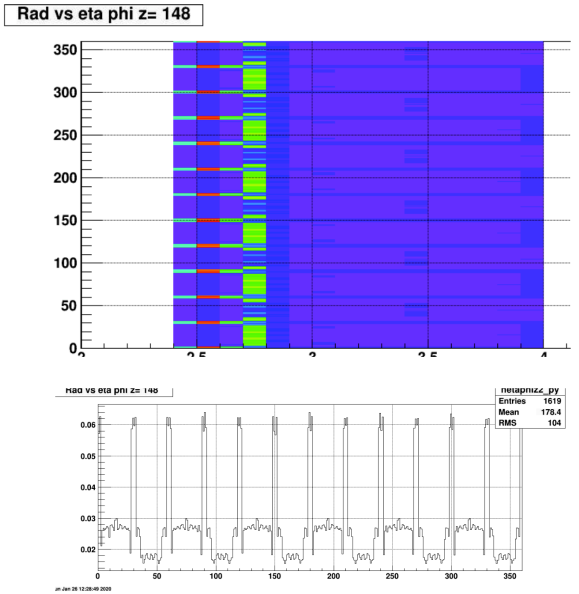
Heat sink:
- ❑ Material: Al 6061
- ❑ Size: ~8.2 x 8.0 x 3 mm^2

The Final Design - Radiation Length

	Main Structure	Heat Sink	Tube
Material	PEEK	Aluminum	Stainless steel
Thickness (mm)	2.27	2.18	1.63
Material budget (X_0)	0.9% X_0	2.5% X_0	9.3% X_0

- http://personalpages.to.infn.it/~tosello/EngMeet/ITSmat/SDD/PPS.html
- http://pdg.lbl.gov/2009/AtomicNuclearProperties/HTML_PAGES/013.html
- www-physics.lbl.gov/~gilg/.../Material/Radiation%20Lengths%20Last.doc



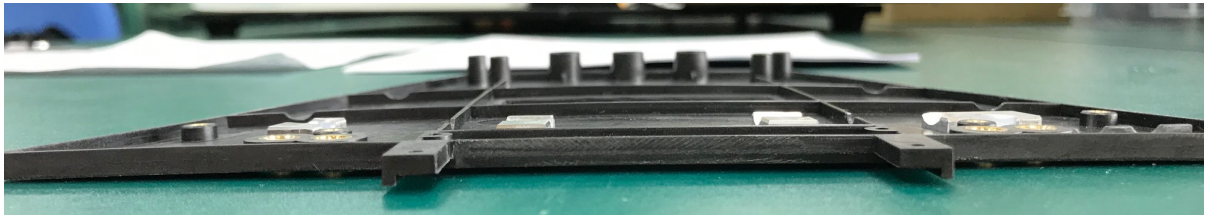


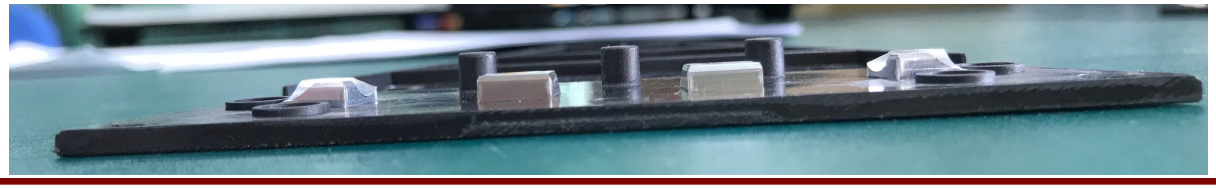
Consistent with GEANT4 (from Flemming, Jan. 27)

- Main feature is the cooling tubes
- Overall 3% for $\eta < 3$
- Otherwise < 1.2%

Main Structure

- Important timeline:
  - 2019-Nov: produced 1st (PEEK+30% CF) and 2nd (PEEK+30% GF) prototype
    - ➔ Obvious flatness issue
  - 2019-Dec: modified the design due to the change of the positions of APV chips and produce 3rd prototype
    - ➔ Flatness issue not solved
  - 2019-Jan: increased the thickness from 1.5 mm to 2.0 mm
    - ➔ Flatness issue not solved
  - 2019-Feb: use pure PEEK
    - ➔ Flatness improved



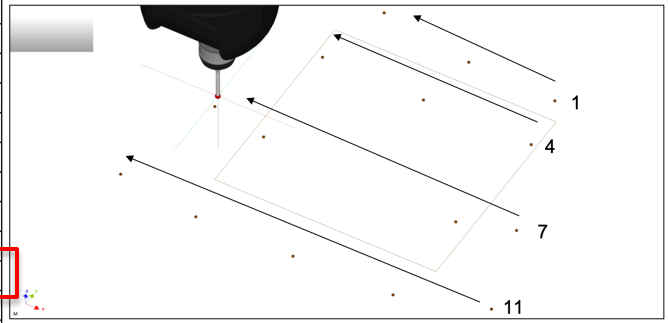


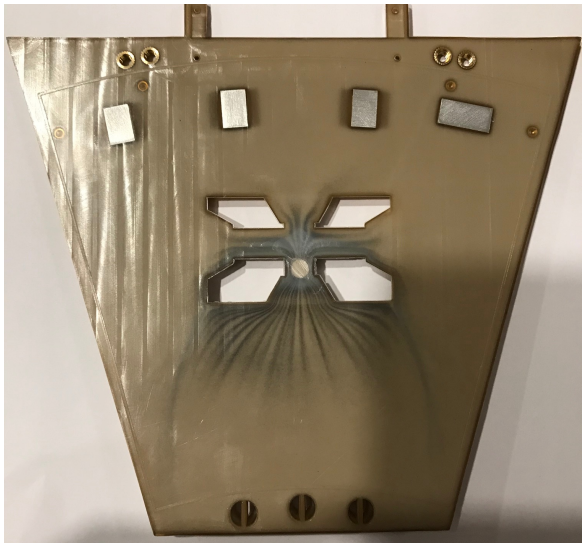
Flatness for the Latest Version

Part 1

Distance to the reference plane

1	0.05
2	0.05
3	0.13
4	0.06
5	0.06
6	0.06
7	0.09
8	0.09
9	0.13
10	0.14
11	0.05
12	0.08
13	0.04
14	0.06
15	0.05
Avg	0.08

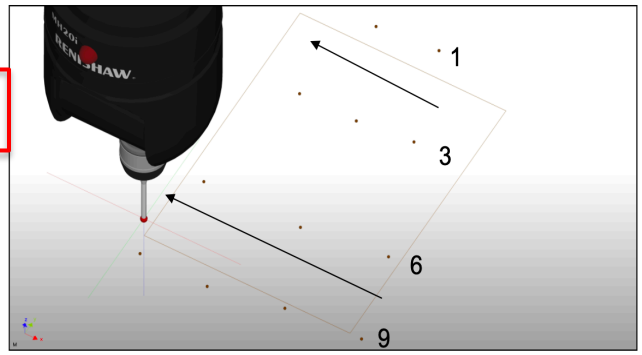




Part 2

Distance to the reference plane

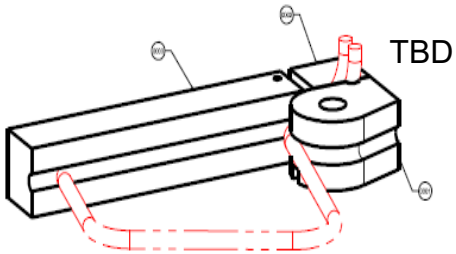
1	0.06
2	0.07
3	0.11
4	0.11
5	0.09
6	0.07
7	0.05
8	0.07
9	0.01
10	0.08
11	0.09
12	0.01
Avg	0.07

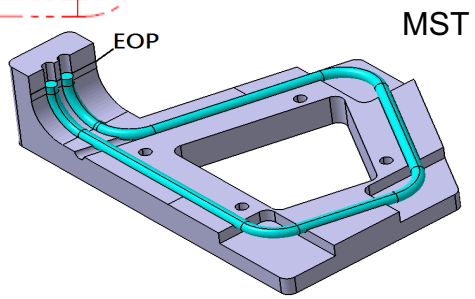


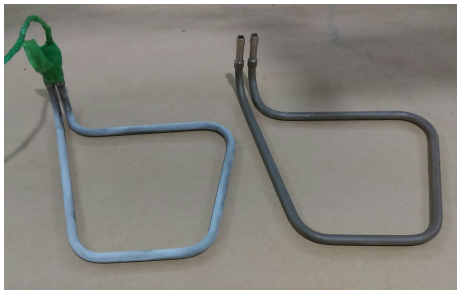
Unit: mm

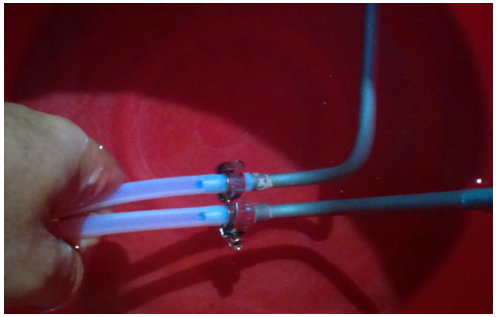
Cooling Tube

- Manufacture procedure (done by AIDC)
  1) Passivation treatment on the raw 316 stainless steel tube
  2) Use Tube Bending Die (TBD) to bend the tube
  3) Use 3D printed Miscellaneous Service Tool (MST) to check the dimensions.
  4) Braze the connectors to the tube
  5) Leakage test
  6) Clean the cooling tube
  7) Plating with Cadmium (Chroming) to prevent electrical corrosion



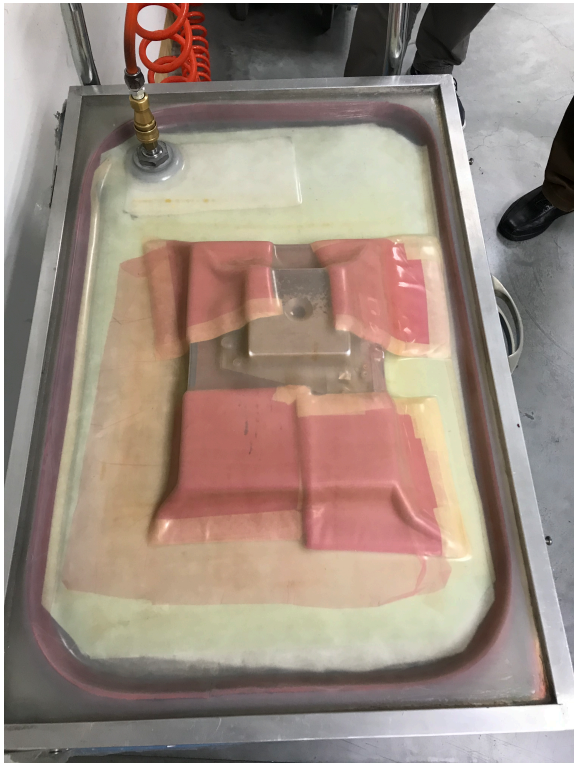


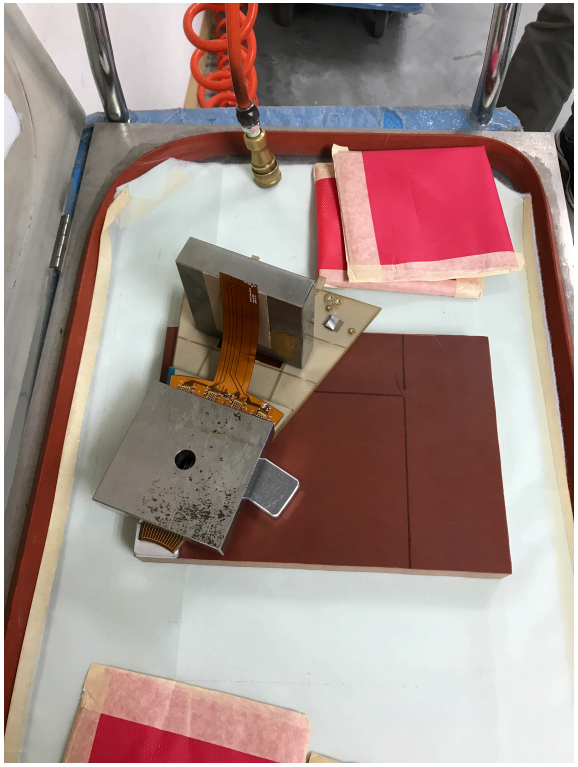




Assembly

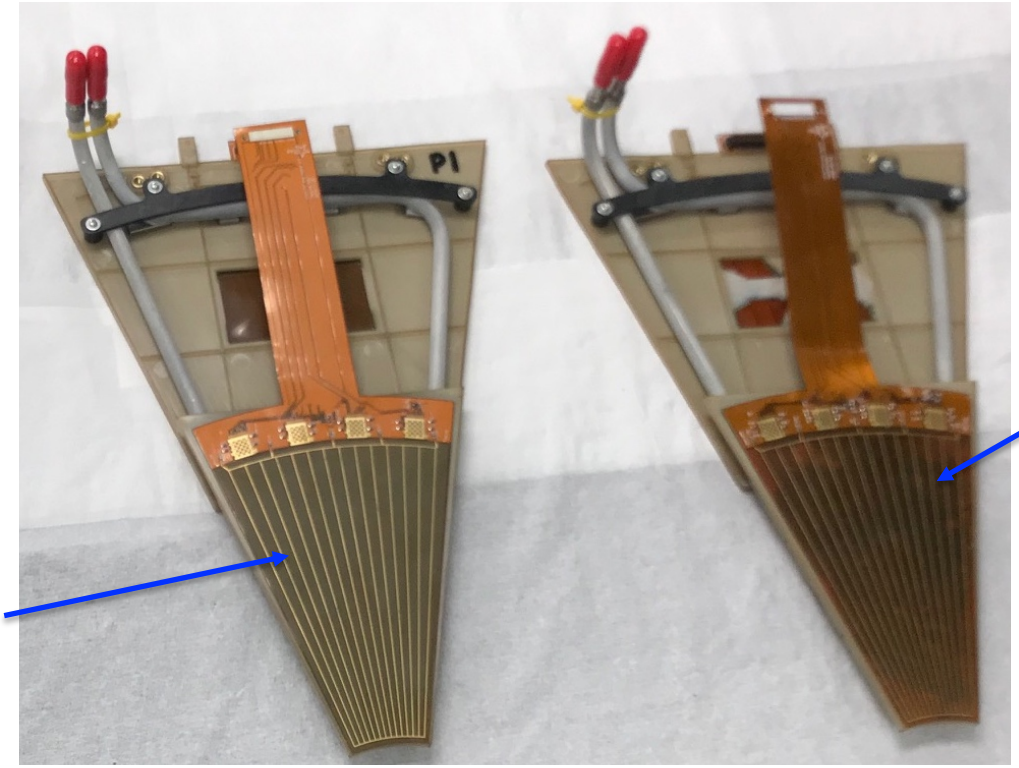
- Preliminary procedure (detailed procedure will be updated in the documentation)
  1) Mount hybrid PCB to the structure
  2) Glue the inner and outer structures together





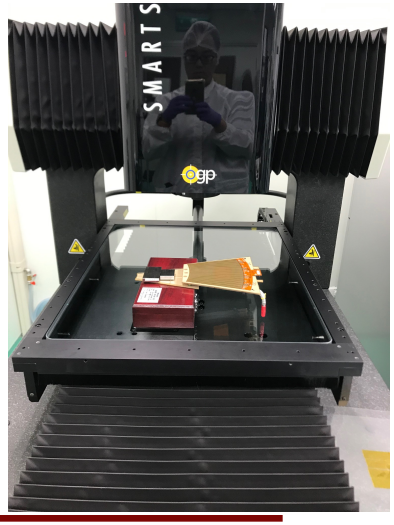
First Batch of Prototypes

- Two prototypes assembled by AIDC on (Jan. 30 and Feb. 11)
- Flatness measured by the silicon lab (for CMS, sPHENIX) at NTU



Thinner hybrid
(older vender)

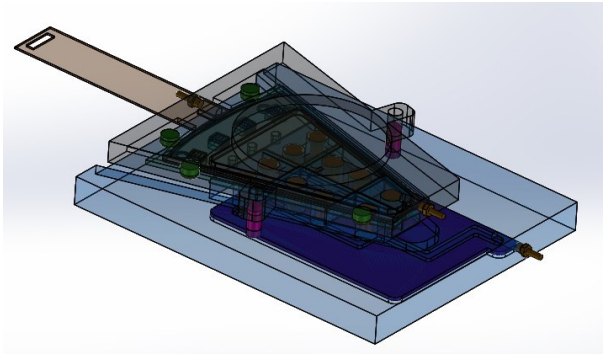
Thicker hybrid
(new vender)

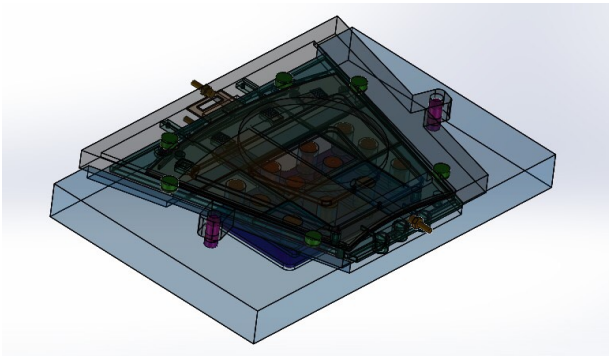


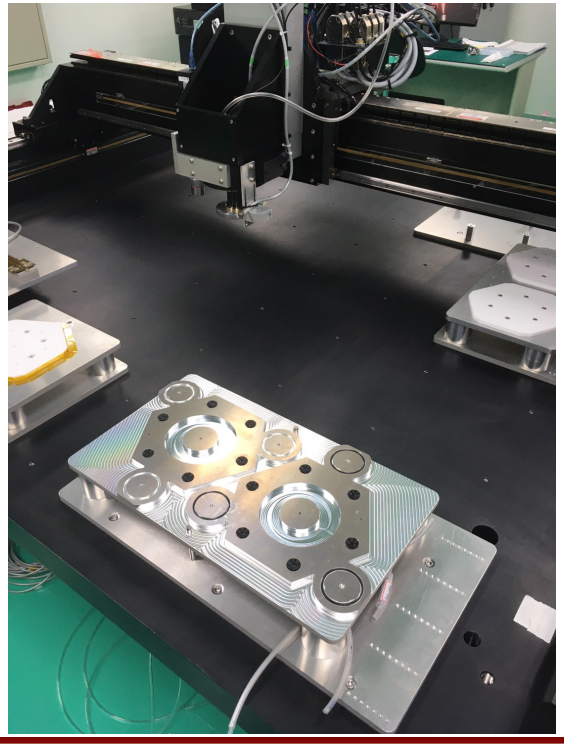
Flatness (RMS)	Thicker hybrid	Thinner hybrid
Inner	0.2942 (mm)	0.2663 (mm)
Outer	0.4654 (mm)	0.2585 (mm)

New Assembly Proposal

- Use the robot machine at the silicon lab of NTU to mount hybrid PCB to mechanical structure
  - ➔ More precise positioning
  - ➔ Need to design the fixtures, modify the LabView code, and optimize the gluing procedure

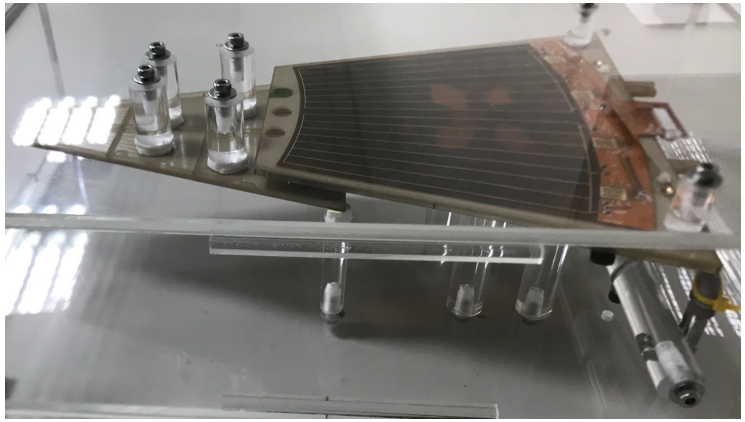


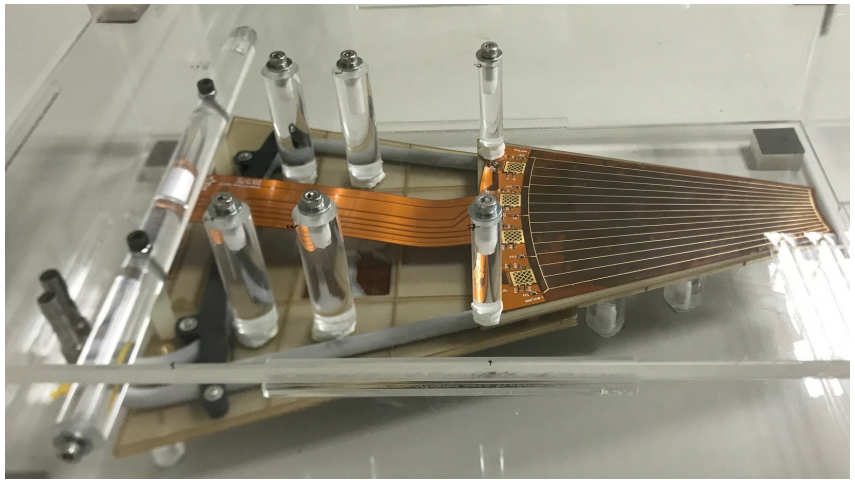


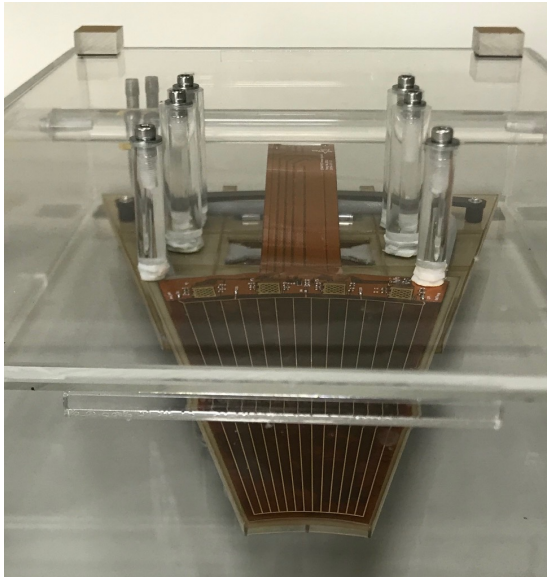


Storage Box

- NCKU designed and manufactured the first two storage boxes
- More details: https://drupal.star.bnl.gov/STAR/event/2020/02/17/fst-group-meeting



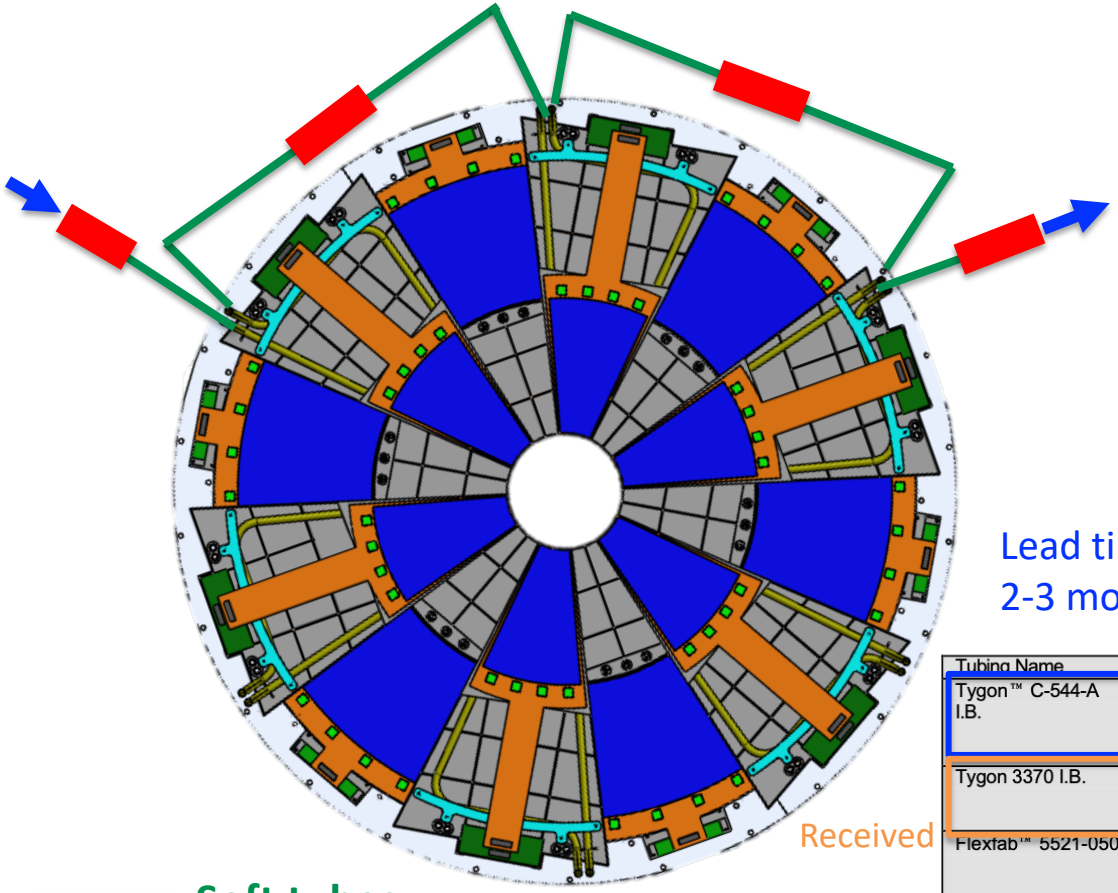




Material: Acryl

Soft Tube and Connector

- Preliminary plan: connect 3 wedges to be 1 set
  - ➔ Total 4 in and 4 out for one disk



Soft tubes

Connector

DME

Price: 30 USD/set

Lead time
2-3 months

Recommended Flex Hoses for General Use

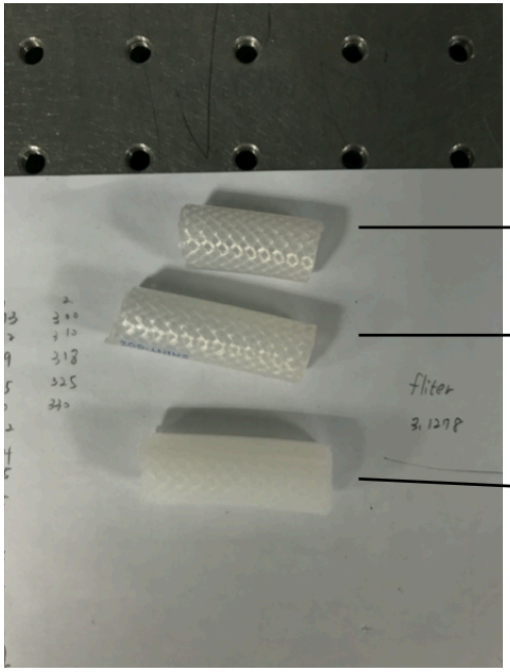
Tubing Name	Type	Extraction %	Weight gain %	Comments
Tygon™ C-544-A I.B.	Clear Braided Polyurethane	0.09	0.3	Excellent Compatibility. Good pressure resistance. Temperature Range –73 to 82C.
Tygon 3370 I.B.	Clear Braided Silicone	1.47	4.8	Good Compatibility. Good Pressure resistance. Temperature Range –73 to 160C.
Flexfab™ 5521-050	Green braided silicone hose	2.08	NA	Good Compatibility. Good Pressure resistance. Temperature range –54 to 150C. http://www.flexfab.com
Nalgene™ 290 PUR	Clear Yellow. No Braid.	0.74	0.3	Excellent Compatibility. Little pressure resistance.

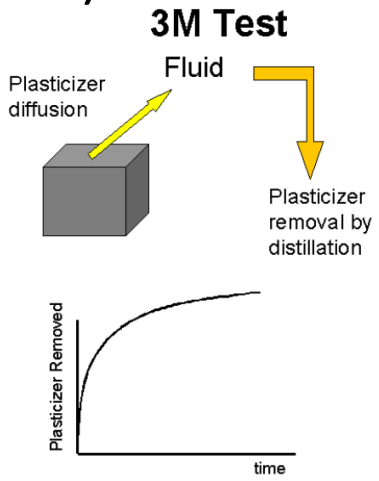
Received

Test of Soft Tube

- Using the Soxhlet extraction method (suggested by 3M)

	Before Test	After 2 hrs	After 8 hrs	After 24 hrs	After 48 hrs
Sample 1	5.66 g	5.56 g (-1.77 %)	in progress	waiting	waiting
Sample 2	4.93 g	4.84 g (-1.83%)	in progress	waiting	waiting





Sample may lose 10g of plasticizer.

May be more accurate for real applications which may have large fluid volumes or sinks for plasticizer

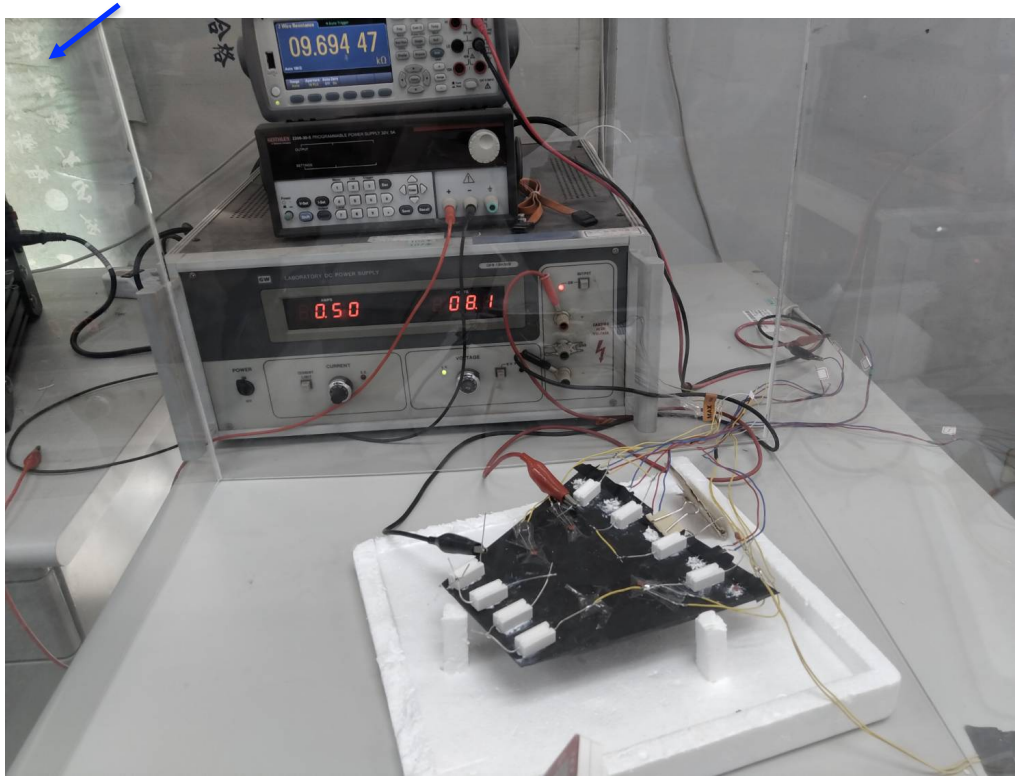
Before testing

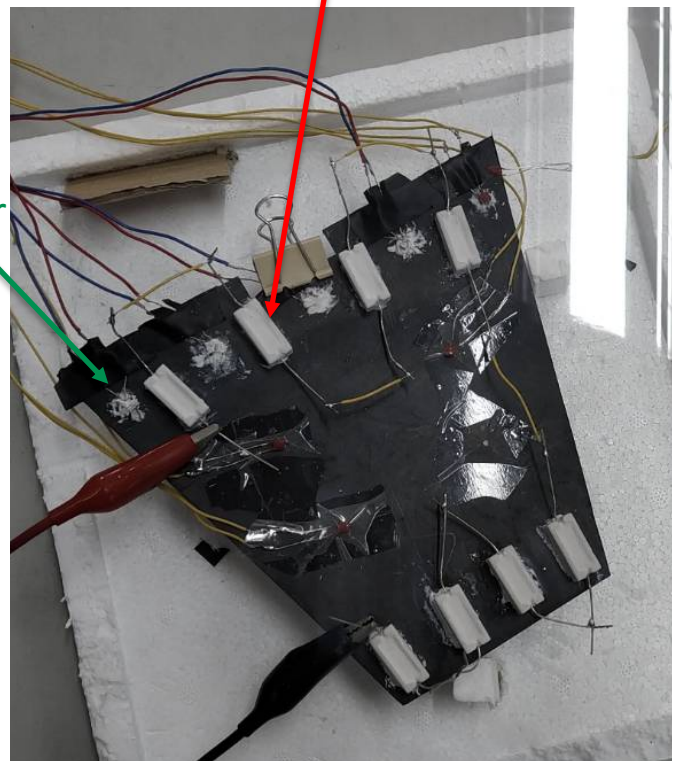
After testing (dry, 5hrs)

Right after testing

Verification of Thermal Analysis

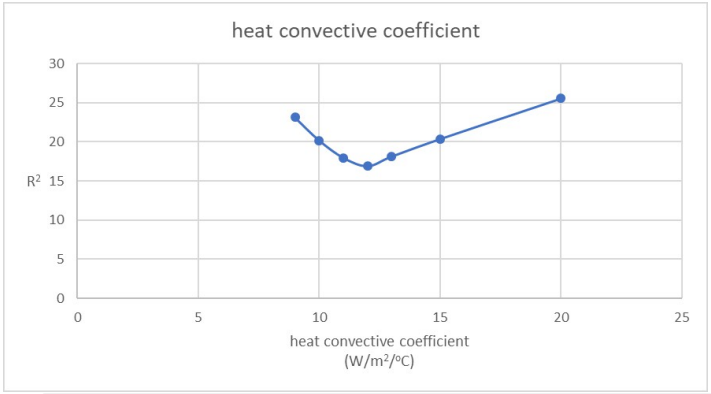
- Setup a simplified experiment using ceramic resistors as heat source and calibrated thermistors to measure temperature
- Done by the students from the mechanical engineering department of NCKU



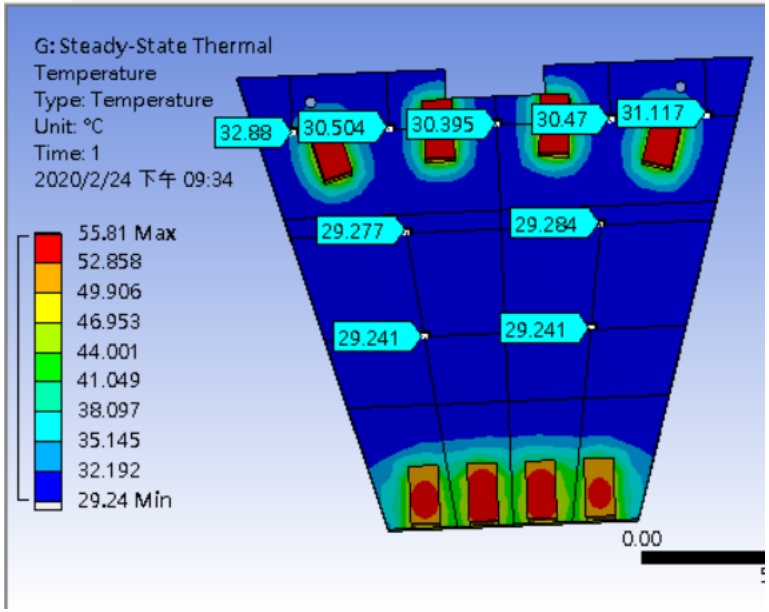


Verification of Thermal Analysis

- Optimize the natural convection coefficient (NCC) in the simulation to match the measured temperature
  - ➔ NCC = 12 W/m^2/K
  - ➔ Good agreement between measurement and simulation



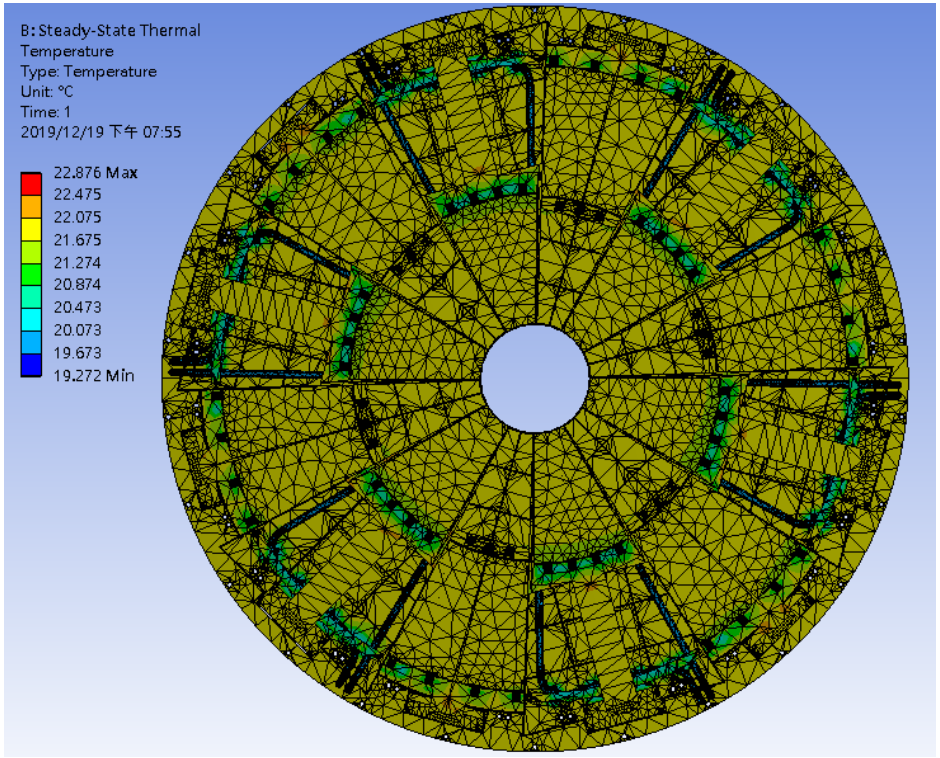
Position	Measured T	Simulated T	Diff. in %
H	30.65	32.63	6.5%
I	31.96	30.49	4.6%
J	31.51	30.40	3.5%
K	32.73	30.47	6.9%
L	30.86	31.13	0.9%
M	30.91	29.28	5.3%
N	28.99	29.24	0.9%
O	30.58	29.28	4.2%



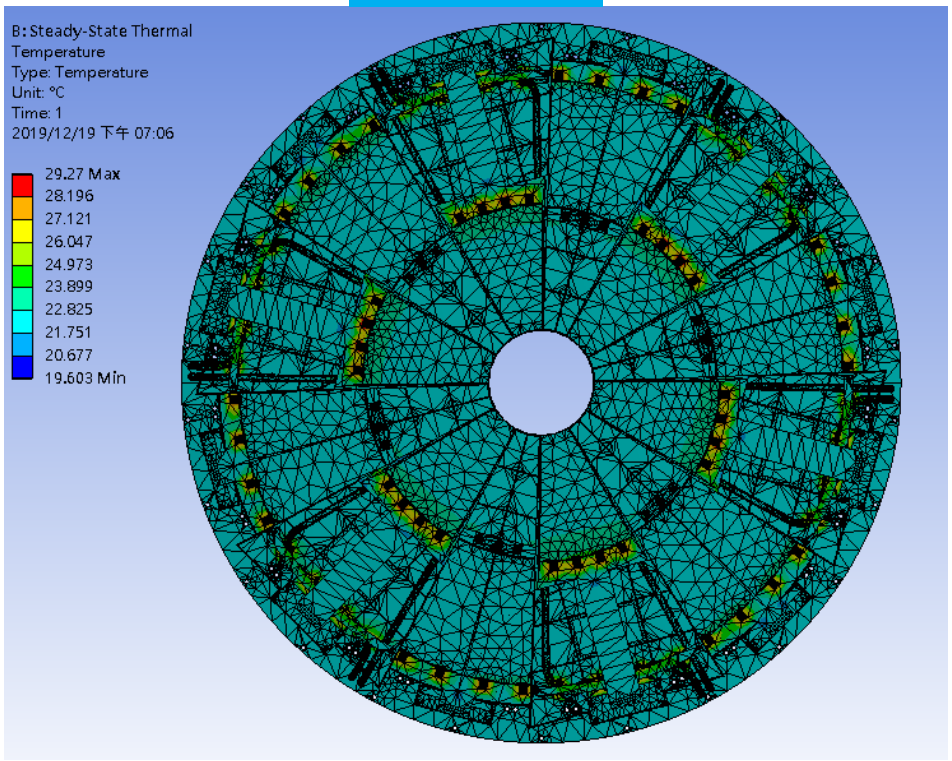
Updated Thermal Simulation

- Use NCC = 13 $W/m^2/K$ to simulate liquid and air cooling scenarios (coolant's temperature = 22 °C)
  - Liquid cooling: maximum ΔT = 0.9 °C
  - Air cooling: maximum ΔT = 9.3 °C

Liquid Cooling



Air Cooling



Schedule for Second Batch of Prototypes

- **Feb. 24 – Mar. 06**: Finish the design of the fixtures for new assembly procedure and try different production parameters on the mechanical structure
- **Mar. 09 – Mar. 18**: Manufacture the fixtures and test the gluing procedure at NTU
- **Mar. 19 – Mar. 25**: Optimize the production procedure
- **Mar. 25 – Mar. 30**: Start the second batch of the prototypes
- **Mar. 31**: Ship to UIC

Backup

The Final Design– Single Wedge